The determination of sorption material properties for water softening in the dynamic conditions

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Abstract. Hardness ions sorption properties of bentonite and paraffine-based material have been studied under dynamic conditions. The temporal characteristics of sorption process have been defined. The comparative analysis of obtained sorbent with cation exchange resin «Lewatit» has been implemented.

1 Introduction

Natural water softening is the urgent problem for many areas of Altai region, where there are almost no surface water sources and available ground water sources are characterized by heightened content of some elements, including the hardness salts. The content of hardness salts can fluctuate from 0,01 mg-Eq/L to 7 mg-Eq/L depending on the category and function of water [2,3].

The traditional softening water methods are chemical and thermochemical methods, reverse osmosis and ion exchange. These methods are high-efficiency, but they demand significant costs of energy and resources. Recently the technologies based on using of sorption and ion exchanging materials from natural mineral raw material are introduced with the purpose of cost minimization on cleaning [4,5].

The most known group of mineral sorbents is the bentonite clay, that forms big deposits in nature and has an industrial value. At present there is a considerable amount of known bentonite deposits in the USA, France, India, Greece, Russia, Kazakhstan, Georgia, Armenia and other countries.

For effective usage of bentonite clay exchange capacity it is necessary to expose clay to preliminary activation for calcium and magnesium ions replacement by more mobile ions (sodium and hydrogen) in the crystal lattice structure [6]. And it is necessary to consider the nature of extractive substance and bentonite content. For metal ions removing from water solutions there are the following types of bentonite clay activations: heat, acid, salt and soda. The conducted research showed a higher efficiency of soda activation with the following extraction of hardness compounds for bentonites of all considered fields compared with other activations [7,8]. We have detected, that the Millos bentonite (Greece) of soda activation has the highest static hardness ions sorption capacity (1,9 mg-Eq/L).

The sorption properties of this clay are comparable with sorption properties of ion exchange resin in the static conditions, named «Lewatit», using for softening.

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In dynamic conditions it is impossible to use bentonite because of high hydraulic resistance and the infiltration carryover with flow. In connection with this research of bentonite clay fixation on different frames including the mineral fiber and waste wood are carried out in the Altai State Technical University at the department of Chemical technique and Engineering ecology [10,11]. The alternative version is paraffin, that can be used as a bonding agent. The obtained material has showed the high denotation of sorption capacity on hardness ions in static condition [9]. Determination sorption parameters in dynamic condition is more important for organization of technological process and so further research has been directed to of full dynamic exchange capacitance of this material studying.

2 Experimental

The research of filtration process through bentonite packing is complicated by high hydraulic resistance due to the ability to swell in the water and fill the loading channels. That is why it has been decided to use the «soft» filtration method, that has been conducted without water slick formation above the filtration material and the water is evenly distributed as a film on its surface.

The full dynamic capacity determination was realized by method GOST 20255.2-89 [12] by the way of water solution filtration of hardness salts through the module with an inside diameter of 35 millimeters, with packing material weight of 40 grams and height of 21 centimeters. Sorbent packing was made layer by layer with distributive grids using, that laid between material layers. The solution quantity flow was 26 ml/minute, the filtration speed was 1,6 meters/hour. The discharge under the material layer was made by vacuum-filter.

The model solution was applied with the content of hardness ions 10 mg-Eq/L, which was used for the preparation of calcium chloride analytical reagent grade and magnesium sulfate heptahydrate. Ions ratio of calcium and magnesium was 2:1, it is more appropriate for natural waters of Altai region. Sample picking of 15-20 ml volume was been realized after every 100 ml of filtrate, after that the sample was analyzed for the content of total hardness by titrometric method with chelating agent III with pH=10 using and indicator Black Eriochrome [13] presence. The process was carried out to equalize the filtrate and working solution.

The full dynamic exchanging capacity (D_n) was calculated in moles per gram (mg-Eq/g) by the formula (1):

$$D_n = ((V_\phi \cdot C - \sum V_n \cdot C_n) \cdot 1000) / m, \quad (1)$$

where: V_ϕ – the total filtrate volume, passing through the material to equalize the filtrate and working solution, cc;

C – concentration of working solution, mole/cdm;

V_n – filtrate portion volume, cc;

C_n – solution concentration in the filtrate portion, mole/cdm ;

m – sorbent weight, g.

The value of full exchange capacity of sorbent was being determined before and after regeneration. The regeneration of researched sorption and ion-exchange material was being implemented by 5% sodium hydrogen carbonate solution, after that there was the washing sorbent off by distilled water.

After the first cycle of saturation (the original material) the value D_n was 0,31 mg-Eq/g, after the second one (the 1st regeneration) it was 0,26 mg-Eq/g, after the third one (the 2nd regeneration) it was 0,21 mg-Eq/g. As it can be seen regeneration reduces the full exchange capacity. The full dynamic exchange capacity of cation resin Lewatit was determined in comparison with the analogical condition, that came up to 0,47 mg-Eq/g after the first cycle of saturation, that is comparable with bentonite-paraffin materials.

In the research process of dynamic capacity the dependencies of ions hardness extraction effectiveness on the bentonite-paraffin materials and cation resin Lewatit from the solution with concentration of 10 mg-Eq/L on the time were determined, that is shown in figure 1.

Fig. 1. The dependence of ions hardness extraction effectiveness (Э) on time (T) on the bentonite paraffin materials and cation resin Lewatit.

For both materials gradual decline of effectiveness with time can be marked. The maximum of softening was 84 % for Lewatit within 20 minutes with the following decrease by 5% within 160 minutes. For paraffin-bentonite material the maximum cleaning effect came up to 80% for the first portion of filtrate with the following decrease. The full saturation was achieved within 110 minutes.

Fig. 2. The dependence of ions hardness extraction effectiveness (Э) and time (T) on the bentonite paraffin materials before and after regeneration.

On figure 2 the curves of effectiveness of ions hardness extraction from solution with concentration 10 mg-Eq/L and time depending on regeneration quantity are shown. It can be seen on picture 2, that after regeneration there are two sites on a diagram: a gradual loss of effectiveness in the interval from 5 to 70 min and a sharp drop after 70 min. It is noted, that the maximum effectiveness made up 77% after the first regeneration, and after the second one it reached 65%. By these curves time parameters of cleaning in dynamic conditions were determined: the time of

protective action (to 50% of cleaning effect) and the time of full dynamic exchange capacity attainment.

On figure 3 there is the duration of the protective action time of filter depending on regeneration quantity (a) and dependence of time of the of full dynamic exchange capacity attainment depending on regeneration quantity (б).

Fig. 3. The dependence of the protective action time of filter (a) and the dependence of the time of full dynamic exchange capacity attainment (б) on regeneration amount.

As it can be seen, after the first regeneration the protective action time falls by 23% (to 43 min), after the second regeneration it is more – by 64% (in comparison with the 1st regeneration).

The time of full dynamic exchange sorbent capacity attainment determination showed that regeneration reduces it (on average by 25%), but it is not reduced depending on the quantity of regeneration.

In spite of the fact that the protective action time reduces significantly after regeneration, the time of full dynamic exchange capacity attainment changes insignificantly, that means, that material can be used before its full saturation.

3 Conclusion

- Betonite and paraffine-based material can be used for water cleaning from the hardness ions. As it has been studied, the effectiveness of cleaning by this material is comparable with of cation resin Lewatit effectiveness.
- The full dynamic exchange capacity of the research material was determined, that came up to 0,31 mg-Eq/g after the first cycle of regeneration, after three regenerations it was 0,21 mg-Eq/g.
- The protective action time and the time of full dynamic exchange capacity attainment have been reduced from 56 to 16 min after the first regeneration and from 112 to 82 min after the second regeneration.

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